

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Civil Engineering



Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	: CVX7242 - Environmental Engineering Design
Academic Year	: 2024/2025
Date	: 05 th March 2026
Time	: 1330-1630hrs
Duration	: 3 hours

General Instructions

1. Read all instructions carefully before answering the questions.
 2. This question paper consists of **Seven (7)** questions in **Six (6)** pages.
 3. Answer any **Five (5)** questions only. All questions carry (20) equal marks.
 4. Answer for each question should commence from a new page.
 5. Relevant charts / codes / equations are provided in last page
 6. This is an Closed Book Test (**CBT**).
 7. Answers should be in clear handwriting.
 8. Do not use red colour pen.
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Question 1

[20 Marks]

- (a) (i) Explain what is meant by "sizing of treatment units" and list three items (besides tank dimensions) that are typically included in the detailed design of a treatment plant.
 (ii) Design a rapid mix basin for $Q = 36,000 \text{ m}^3/\text{day}$. Target detention time (t) is 45 s for rapid mixing. Compute basin volume (V) (m^3). (3)
 (iii) Provide one practical basin dimension set ($L \times W \times D$) with ($D=3.0$) m of rapid mix basin.
 (iv) design a 3-stage flocculator. Stages are with equal volume and 2 parallel trains (same size). Compute total flocculation volume and volume per train. Total flocculation time = 25 min and Tank water depth = 4.0 m
- (b) A rectangular settling tank has:
 Flow per tank = $20,000 \text{ m}^3/\text{day}$
 It has 2 end weirs, each length = 18 m
 Acceptable weir loading limit = $250 \text{ m}^3/\text{m} \cdot \text{day}$
 (i) Compute actual weir loading ($\text{m}^3/\text{m} \cdot \text{day}$). (4)
 (ii) State whether it complies. (1)
 (iii) If not, compute the additional weir length needed. (3)
- (c) Design sedimentation for $Q = 40,000 \text{ m}^3/\text{day}$.
 Criteria:
 • Surface overflow rate (SOR) = $30 \text{ m}^3/\text{m}^2 \cdot \text{day}$
 • Detention time (t) = 2.5 h
 • Side water depth (SWD) = 3.5 m
 • Length:Width ratio = 4:1
 • Provide 2 tanks in parallel
 (i) Compute total surface area required and area per tank. (3)
 (ii) Compute tank plan dimensions (L and W). (3)
 (iii) Compute horizontal velocity (m/min) in each tank. (2)

Question 2

[20 Marks]

- (a) Design rapid sand filtration for $Q = 32,000 \text{ m}^3/\text{day}$.
 • Filtration rate = $6.0 \text{ m}/\text{h}$
 • Provide 1 standby filter (i.e., one extra)
 • Assume filters operate 24 h/day
 • Each filter is $6 \text{ m} \times 8 \text{ m}$ (plan area fixed)
 • Allowable number of filters must be integer
 (i) Compute required total filter area.
 (ii) Compute total number of filters including standby.

(b) A filter backwash uses:

- Backwash rate = $45 \text{ m}^3/\text{m}^2 \cdot \text{h}$
- Filter area = 48 m^2
- Backwash duration = 8 min
- Provide 15% extra volume for losses
- (i) Compute backwash flow (m^3/h and L/s). (3)
- (ii) Compute required backwash volume (m^3) incl. 15% extra. (3)
- (iii) Compute pump hydraulic power and motor power (kW) assuming motor efficiency = 90%.

(c) Design chlorination for $Q = 25,000 \text{ m}^3/\text{day}$.

- Chlorine demand = 1.8 mg/L
- Target residual after contact = 0.5 mg/L
- Apply 10% safety factor on dose
- Chlorine is applied as sodium hypochlorite (NaOCl) solution:
- Available chlorine = 12% by weight
- Solution density = 1.20 kg/L
- Storage required for 14 days
- (i) Compute chlorine dose (mg/L).
- (ii) Compute daily chlorine mass required (kg/day).
- (iii) Compute NaOCl solution volume per day (L/day).
- (iv) Compute storage tank volume for 14 days (m^3).

Question 3

[20 Marks]

- (a) (i) Define an attached growth biological treatment system and list three examples used for domestic wastewater treatment.
- (ii) Explain the removal mechanism in a trickling filter, including the terms biofilm/slime layer and sloughing.
- (b) (i) Describe the concept of an RBC and state why primary treatment is considered an integral part of an RBC system.
- (ii) List any three RBC design criteria
- (iii) An RBC is required to treat $Q = 2,400 \text{ m}^3/\text{d}$ of settled wastewater with influent soluble $\text{BOD}_5 = 200 \text{ mg/L}$ and target BOD_5 removal of 75%.
- Assume RBC organic loading design criterion = $8 \text{ g BOD}_5/\text{m}^2 \cdot \text{d}$ (within the given range).
- Calculate:
- (a) BOD_5 removed per day (kg/d)
- (b) Required total disc surface area (m^2)

- (c) A settling tank is designed for average daily flow ($Q_{\text{avg}} = 1,200 \text{ m}^3/\text{d}$). Assume surface loading rate (SLR) = $40 \text{ m}^3/\text{m}^2 \cdot \text{d}$ and L:B = 3:1.
- Determine required surface area (A_s) (m^2) using ($A_s = Q/\text{SLR}$).
 - Determine L and B (m).
 - If net depth $D = 3.0 \text{ m}$, compute tank volume (m^3) and the corresponding HRT (hours) using ($t = V/Q \times 24$).

Question 4**[20 Marks]**

- (a) A wastewater has BOD_5 at $20^\circ\text{C} = 250 \text{ mg/L}$ and the first-order BOD rate constant (base e) is $K' = 0.35 \text{ d}^{-1}$.
- Calculate, Ultimate BOD, (L_0) (mg/L)
 - 3-day BOD, (L_3) (mg/L) [10 marks]
- (b) (i) Explain the meaning of F/M ratio and state two effects of operating at (a) very high F/M (b) very low F/M on sludge settleability/effluent SS.
- (ii) A complete-mix aerobic bioreactor treats $Q_0 = 6,000 \text{ m}^3/\text{d}$. Influent and effluent BOD_5 are $S_0 = 240 \text{ mg/L}$ and $S = 30 \text{ mg/L}$.
The aeration tank volume is $V = 2,000 \text{ m}^3$ and $\text{MLSS (X)} = 3,200 \text{ mg/L}$.
- Calculate the F/M ratio (d^{-1}) using the organic loading
 - Estimate the theoretical oxygen requirement ($\text{kg O}_2/\text{d}$)
- (c) A city discharges $5.25 \text{ m}^3/\text{s}$ of wastewater into a stream whose minimum rate of flow is $4 \text{ m}^3/\text{s}$. At this condition, the stream BOD_5 concentration is 12 mg/l and the BOD_5 of the pollutant at the outfall is 300 mg/l above the outfall. Determine the BOD_5 at the downstream stream of wastewater receiving body.

Question 5**[20 Marks]**

- (a) (i) Define field capacity in the context of landfill cover soil and waste, and explain its role in the onset of leachate generation.
- (ii) List the main components in a landfill water balance used to estimate leachate generation.

(b) A landfill site has the following annual hydrologic data:

- Precipitation ($P = 1,250$) mm/year
- Runoff coefficient ($R = 0.18$)
- Evapotranspiration ($E = 720$) mm/year

Assume storage change ($S = 0$) mm/year. Using the water balance equation

- (i) Calculate the percolation (C) (mm/year).
- (ii) If the landfill footprint area is 0.32 km^2 , estimate the annual leachate quantity (m^3/year) assuming all percolation becomes collected leachate.

(c) (i) State two reasons why landfill gas must be controlled (migration/explosion risk, greenhouse gas impacts, etc.). [03 marks]

(ii) A sanitary landfill has available airspace $= 1.20 \times 10^6 \text{ m}^3$. The community disposes 220 tonnes/day of MSW. Assume in-place compacted density $= 700 \text{ kg/m}^3$ (typical). Daily cover consumes 25% of total landfill volume. Estimate the expected landfill life (years).

(Use 365 days/year; account for cover by letting (T) be total required volume: ($T = V_{\text{waste}} + 0.25T$)).

Question 6

[20 Marks]

- (a) (i) Define sound and noise and explain why a falling tree can “make sound” but not necessarily “noise.”
 - (ii) State the meaning of frequency (Hz) and amplitude in a sound wave and give the typical audible frequency range for healthy human hearing.
 - (iii) A highway noise barrier is installed to protect a row of houses. Explain what is meant by a noise barrier shadow zone and why the reduction is not “perfect” like a light shadow.
- (b) (i) At a location near a roadway, the measured RMS sound pressure is ($P = 0.20 \text{ N/m}^2$). Calculate the SPL (dB) at that location.
- (ii) At a receiver point, three independent sources contribute the following sound pressure levels:
- Source A: 72 dB
 - Source B: 68 dB
 - Source C: 61 dB
- Calculate the total sound level at the receiver (dB).

- (c) A plant produces 1,800 kg/d of digested dry solids (assume mixed primary + activated sludge after digestion). Design sludge drying bed area using the criterion 60–120 kg dry solids/m² yr.

Calculate:

- (i) Annual dry solids (kg/yr)
- (ii) Required bed area (m²) using 80 kg/m² yr
- (iii) Number of beds if each bed is 20 m × 6 m and allow 10% extra area for walkways/berms.

Question 7

[20 Marks]

- (a) An air pollution control device receives a particulate-laden gas stream at a concentration of 110,000 µg/m³ and a flow rate of 150 m³/s. The device collects 0.40 metric ton/day of particulate.

Calculate:

- (i) Particulate mass entering the device (g/s)
- (ii) Particulate mass escaping (g/s)
- (iii) Emission concentration (µg/m³) of the gas leaving the device

- (b) (i) With brief explanations, describe any three plume types associated with atmospheric stability (e.g., looping, coning, fanning, fumigation) and state which stability condition tends to produce each.

(ii) Define effective stack height (H) and explain why it is used in dispersion calculations.

(iii) A power station stack has:

- Stack exit velocity ($V_s = 4.0$) m/s
- Stack diameter ($d = 1.8$) m
- Average wind speed ($u = 5.5$) m/s
- Atmospheric temperature ($T_a = 30^\circ\text{C}$)
- Stack gas temperature ($T_s = 160^\circ\text{C}$)

Assume neutral stability and take lapse rate = 0.01

Calculate the plume rise in m).

- (c) A coal-fired industrial boiler emits sulfur dioxide (SO₂) through a single stack. The following data are provided:

- SO₂ concentration in stack gas (dry, corrected to reference O₂) = 1,500 mg/Nm³
- Stack gas flow rate (dry, standard conditions) = 25 Nm³/s
- Stack exit temperature = 180°C
- Ambient air temperature = 30°C

- Stack gas molecular weight $\approx$ air (assume 29 kg/kmol)
- Wind speed at stack height = 5 m/s
- Required minimum exit velocity $= \geq 15$ m/s (to avoid downwash)

Assume ideal gas behavior.

- Calculate the SO_2 emission rate in g/s.
- Determine the minimum internal stack diameter (m) required to ensure an exit velocity of at least 15 m/s.
- State two factors (other than exit velocity) that influence stack height selection for effective pollutant dispersion.

Note: For stable condition, the prevailing lapse rate is $1^\circ\text{C}/100\text{m}$, the change in temperature with elevation; $F = \{gV_s d^2(T_s - T_a)\}/4(T_a + 273)$; $S = g/(T_0 + 273) \times [\Delta T/\Delta z + 0.01]$; $\Delta H = 2.6 \{F/uS\}^{1/3}$ are given with usual notations.

----- End -----

Supplementary

$$r_u = -\frac{\mu_m S X_{avg}}{K_s + S}$$

$$\frac{1}{\theta_c} = \frac{Y \mu_m (S_o - S)}{(S_o - S) + (1 + \alpha) K_s \ln(S_i/S)} - k_d$$

$$\frac{F}{M} = \frac{Q S_0}{V X}$$

$$DO = DO_s - \left[\frac{k_d L_0}{k_r - k_d} (e^{-k_d t} - e^{-k_r t}) + D_0 e^{-k_t t} \right]$$

$$t_c = \frac{1}{k_r - k_d} \ln \left\{ \frac{k_r}{k_d} \left[1 - \frac{D_0 (k_r - k_d)}{k_d L_0} \right] \right\}$$

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$$: C = P(1-R) - S - E$$